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THE CALCIUM REQUIREMENT OF ADULTS

By RUTH WOODS

Although bones and teeth are already formed in adults and only very small amounts of calcium are needed for other vital body functions, recent research has shown a greater need for calcium in the adult than formerly recognized. This is so for three reasons: (1) There is a constant endogenous loss of calcium ions from the body. This daily loss varies tremendously in individuals, but is sufficiently large so that if not replaced, calcium is drained from the bones to make up the deficit. (2) Extra calcium intakes are stored in the trabeculae of the bones. This constitutes an essential reserve in cases of emergency such as the repair of bone fractures or the increased demands in women during pregnancy and lactation. Lack of such calcium stores in these emergencies may cause a drain of calcium from the bones. A severe case of such loss causes osteomalacia, the adult counterpart of rickets. Extensive pathological investigation, as pointed out by Sherman (1a), has shown that doubling a normal food calcium intake does not increase the incidence of abnormal calcification in the body in walls or other soft tissues. (3) Adults (and children, too) do not utilize 100% of the calcium of their foods even in foods such as milk whose calcium is most available. Recent findings show that only 15 to 35% of the dietary calcium can be used by man.

For these reasons, the National Research Council has suggested in its newly revised Recommended Daily Allowances, that the calcium requirements of all adults, regardless of size, weight or activity, be increased by 25% from 0.8 g. to 1.0 gram per day.

Estimating Human Calcium Requirements:

Factors Involved: The determination of what constitutes a suitable daily intake of calcium is a complex matter. Assuming normal absorption and utilization of the calcium provided by common foods, there still remain a large number of factors which influence the individual requirement for this element. These include the basic needs of different age and sex groups, plus the varying requirements which may be superimposed upon these needs because of changing physiological conditions. Thus, consideration must be given to the basic maintenance requirement in adults, the special needs of growth during infancy, childhood and adolescence, the altered requirements during pregnancy and lactation. In addition, proper evaluation must be made of the dietary sources of calcium because of the wide variations in availability of this mineral from different food sources. The relation to phosphorus, iron, vitamin D and citrates must also be considered because

these are some of the more important dietary factors which influence the metabolism and utilization of calcium in the body.

The Balance Method: The majority of studies on human calcium requirements have employed some modification of the so-called balance method. The essence of this method is the determination by feeding experiments of the minimum amount of calcium which must be supplied in the diet to permit the body to establish and maintain an equilibrium between its intake and output of this element. Theoretically, calcium balance studies are simplest when carried out on adults in whom calcium is normally required for maintenance purposes only; in other words, chiefly to replace daily losses from the body. The estimation can thus be free of complicating factors such as extra calcium requirements for bone and tooth formation or other special functions. Even for the relatively simple requirements of adults, however, there are several factors which have been introduced as being essential to proper evaluation of the data obtained from simple balance studies. These include the postulated relation of calcium requirements to either body weight or, perhaps, surface area and the percent of dietary calcium which is estimated to be utilized by the average adult.

The Calcium Requirement for Maintenance: The maintenance requirement for calcium, and for other inorganic elements as well, must be judged quite differently from that of an organic nutrient. Organic nutrients — such as the fats, proteins, carbohydrates or vitamins — are broken down into simpler units and merged into a common metabolic pool from which they may emerge either reconstructed into new essential compounds or further broken down to non-utilizable end products of metabolism which are excreted as waste from the lungs, skin, kidney and intestines. In this way, there is a large daily loss of organic elements from the body.

With the minerals, on the other hand, there is no such breakdown and disposition of useless material. These materials do not become unavailable since they are not altered or destroyed in the processes of metabolism. These inorganic minerals are just as available for the reconstruction of new body cells, tissues or enzymes; or for the maintenance of proper osmotic pressure or of the hydrogen ion concentration of the blood, when they are released through metabolic processes as when they are picked up as inorganic ions by the blood from the dietary supply in the intestinal tract. Therefore, in the adult, the maintenance requirement for calcium represents merely a mechanical leakage of calcium ions through the kidney, the digestive glands and the lining of the intestinal tract due entirely to simple physico-chemical processes.

The extent of this inevitable loss of calcium from the body can be determined by measuring the output of calcium in the urine and feces of subjects maintained on low calcium diets.

Calcium Balance Studies—Early Interpretations:

The first comprehensive analysis of existing data on calcium balances in adults was published in 1920 by Sherman (1) of Columbia University. He compiled a table of 97 experiments, the majority from his own laboratory and the rest from the existing literature, in which was recorded the daily output of calcium of subjects on low calcium diets, calculated to a standard body weight of 70 kilograms. The calcium excretions showed an extreme range of from 0.27 to 0.82 grams of calcium, with an average of 0.45 gram. In most of these studies, equilibrium was not reached; the calcium balances were generally negative.

The average amount of calcium excreted by the body under these conditions of low calcium intake, namely 0.45 gram, was tentatively used as an indication of the body's need for calcium. In other words, if 0.45 gram was excreted, then the body probably required the same amount in the daily diet to overcome this loss. Because most of the subjects were in negative balance, however, Sherman suggested that this simplifying assumption would tend to low results and recommended, therefore, a 50 per cent margin of safety increase over the minimum estimate of 0.45 gram. This brought the first tentative dietary standard for calcium to 0.68 gram per adult per day.

Some years later, the early data examined by Sherman as well as additional data accumulated in the following years, were reexamined by Leitch (2). By graphical computation of the data she attempted to estimate the calcium intake level at which the chances of a positive or negative balance would be about equal. By this means she arrived at an average daily calcium requirement of 0.55 gram for maintenance. No apparent correlation was found by this method between calcium excretion and body weight; therefore Leitch set the requirement of 0.55 g. for all adults regardless of size.

Mitchell and Curzon (3) have stated that it is hardly conceivable that the endogenous daily losses of calcium in urine and feces would be independent of body size, although such correlation is difficult to prove in the manner demonstrated by Leitch. These workers attribute this failure to the effect of variations in the diets used, both with respect to their actual calcium contents and the foods used as sources of calcium. Citing the data of Bauer *et al* (4) on subjects receiving similar diets and varying in weight from 40 to 81 kg., they report evidence that high excretions of calcium

are generally associated with heavier subjects. Based on their assumption that calcium output is related in some way to body weight, Mitchell and Curzon analyzed the data on some 139 experiments (107 subjects) not in their original form of grams of calcium daily, but in the form of grams of calcium eaten or excreted per kilogram of body weight. This analysis, based on the data of Sherman (1), Leitch (2), Bauer *et al* (4) and many other investigators, was plotted graphically as illustrated in Fig. 1.

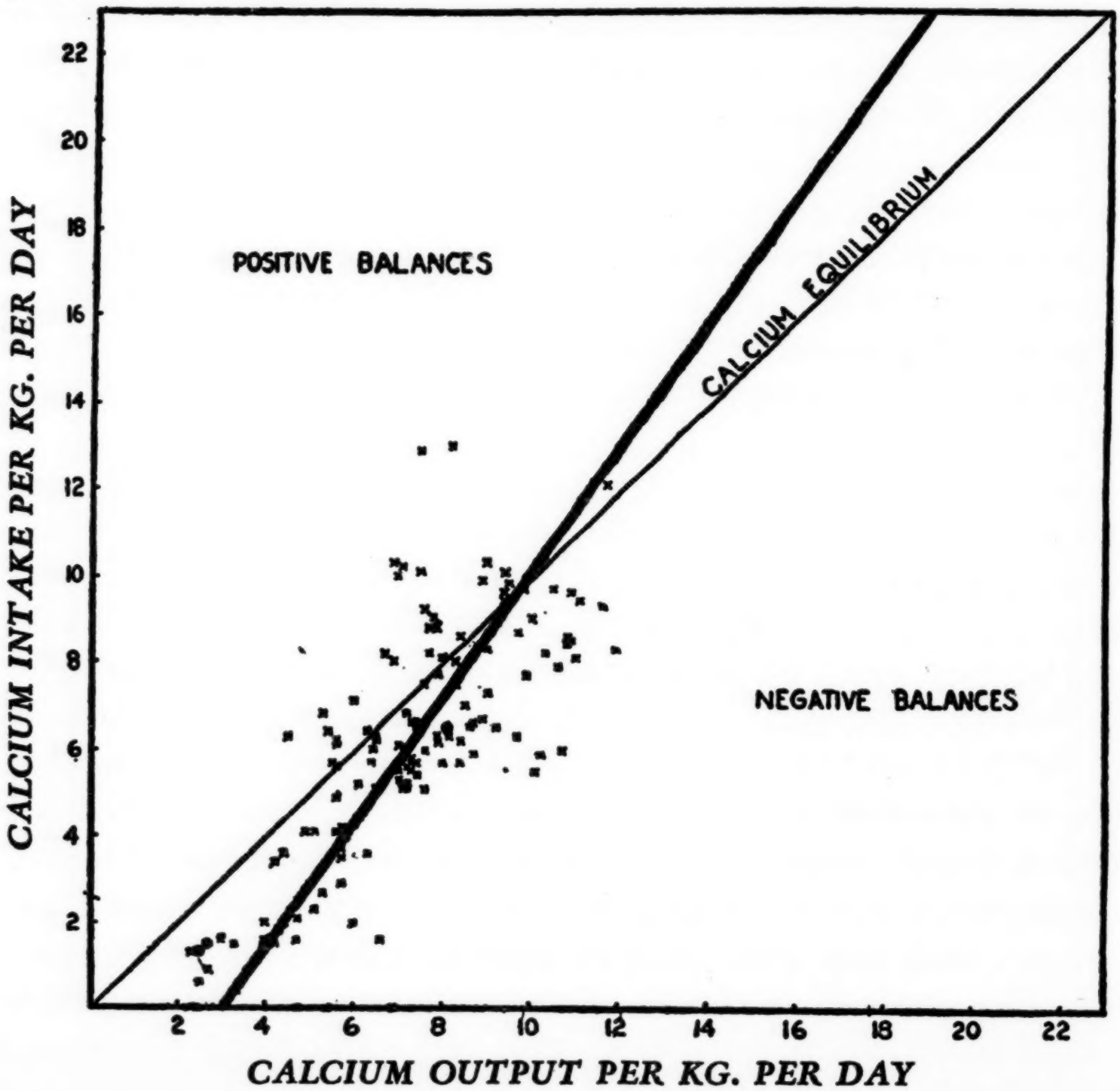
FIG. 1

The diagonal line divides the chart in two areas, that above and to the left of the diagonal line in which the data corresponding to positive calcium balances are plotted, and that below and to the right for negative balances. The data are all expressed in mgms. of calcium per kg. of body weight per day.

The unbroken line was fitted to the data by the method of least squares and possess the formula:

$$y = .6826x + 3.0940$$

Where y is the calcium output in mgms. per kg. body weight, and x is the intake of calcium expressed in the same fashion.



The relationship between the intake and output of calcium in 139 selected metabolism experiments on human subjects. All results expressed in milligrams of calcium per kilogram of body weight per day.

Examination of this graph reveals that the heavy line (see explanatory note below Fig. 1) intersects with the *x* axis (intake) at 3.09 mgms., giving the average endogenous excretion. This occurs only when the calcium intake is reduced to zero (as in fasting experiments). The same line intersects with the light diagonal line representing equilibrium only at an intake of 9.75 mg. per kg. body weight per day. This gives the average intake of calcium required for equilibrium. Computed to an average 70 kg. adult weight, this would be an average daily maintenance requirement of 0.68 g. calcium as compared with Sherman's estimate of 0.45 g. and Leitch's of 0.55 g.

Percentage Utilization of Calcium:

Based on their graphical interpretation of the available information on calcium balance studies, Mitchell and Curzon were led to conclude that dietary calcium is not 100 per cent available to the human body. They suggested that the efficacy of dietary calcium in replacing endogenous body losses may be expected to vary with the kinds of food materials contained in the diet. From their finding that the average loss of calcium is 3.1 mg. per kg. of body weight per day (on ordinary mixed diets), while the average intake of dietary calcium required to maintain equilibrium is 9.75 mg. per kg. per day, they demonstrated that slightly more than 3 mg. of dietary calcium are required on the average to replace an endogenous loss of 1 mg. This means that the average adult utilizes only about 30 per cent of the calcium content of most foods.

Calcium Balance Studies—Newer Findings:

Percentage Utilization and Requirement: In view of the obvious indication that dietary calcium is not completely utilized, Steggerda and Mitchell (5) conducted a controlled experiment in an attempt to confirm this conclusion. The varied experiments from which they had culled their earlier data were too disparate to afford conclusive evidence partly because of metabolic differences among the experimental subjects; partly because of the short experimental periods used; and partly because of differences in the dietary sources of calcium.

Accordingly, a study was made of the calcium balance of an adult human subject receiving a basal low-calcium diet with varying supplements of calcium over forty-three four-day periods. It was found that the daily addition of 540 mg. of calcium to the basal diet containing 195 mg. of calcium changed the daily calcium balance from an average of—110 mg. to approximately 0. In other words 540 mg. of calcium were required to replace an

endogenous loss of 110 mg., indicating a utilization of the dietary calcium of about 20 per cent. Equilibrium in this subject was obtained on a total intake of 735 mg. of calcium (540 + basal 195 mg.), which when calculated to the body weight of the subject, was equivalent to 9.2 mg. per kg. as compared to the earlier estimate (3) of 9.75 mg.

In this study both milk and a calcium salt, calcium gluconate, were used as sources of supplementary dietary calcium. The calcium of both these products was equally well utilized, but only to the extent of 20 per cent.

Studies by other workers on calcium storage (retention) and loss at different levels of calcium intake when milk or ice cream supplied from about 80 to 94% of the dietary calcium show general agreement with the requirement of 9.2 mg. per kg. per day (6, 7, 8, 9). Other investigators, however, found that diets providing as little as 6.4 to 8.2 mg. per kg. of calcium daily, largely from milk, could promote calcium storage in adults for short periods of time (10, 11, 12, 13). These latter studies are interpreted by Steggerda and Mitchell as being indicative of wide variations in the utilization of calcium in a particular food.

Utilization of Milk Calcium: Two years after the publication of the first experiment designed to measure specifically the utilization of calcium in a single adult subject (5), Outhouse and coworkers (14, 15) extended this field of investigation by similar studies on a group of seven adults. The purpose of their studies was two-fold: (1) to determine the utilization of calcium from milk, reputedly one of the best sources of calcium, and (2) to estimate the adult requirement for calcium by balance studies.

Because of the richness of milk in calcium, nutritionists have classified this food as nearly indispensable in the American diet. Numerous studies have shown, however, that mere measurement of the calcium content of a food is no indication of its value as a dietary source of this element—the true value of the food depends on whether the body can utilize the calcium present in it. The classic example of this is the well-known distinction between the high calcium content of spinach and its complete unavailability to the body because of the presence of oxalic acid (16).

Method: The method for determining percentage utilization differed from that of Mitchell and Curzon (5). Calcium was fed at two levels of intake, but because a maximal value for calcium utilization could not be assured if the adults were in calcium equilibrium, both levels were designed to provide less than the maintenance requirement; in other words to induce negative balances. The lower of the two intakes was provided by a basal diet; the higher was derived from the specific food being tested (milk)

which was added to the basal diet. If a smaller calcium deficit existed when this food was being tested, it would follow that the calcium of the test substance was being utilized. A quantitative measure of its utilization was secured by the following formula:

$$\frac{\text{Net losses during basal period — net losses during test period}}{\text{Intake during test period — intake during basal period}} \times 100$$

The following values for calcium utilization for seven adults were obtained by this method: 15.3, 17.6, 20.1, 20.4, 30.3, 30.6, 35.1%. No explanation for the division of subjects into high and low utilizers could be found on any basis, such as weight, leanness, previous degree of calcium saturation, etc. A general average of about 24% utilization agrees fairly well with that for Steggerda and Mitchell's figure of 20%.

In a continuation of their studies on these seven adults, Outhouse *et al* (15) attempted to estimate requirements for each of the subjects based on their individual abilities to utilize calcium. Each subject received a daily basal diet containing 270 mg. calcium. To this were added milk supplements in varying amounts almost sufficient to induce calcium equilibrium. The amount of the supplements was determined by each individual's calculated utilization of milk calcium (14). The daily requirements were computed by applying to the data (Table 1) the following formula: (see page 8)

$$\text{Calcium Requirement} = \text{Calcium Intake} \pm \frac{\text{Calcium balance}}{\%\ \text{Utilization of milk calcium}} \times 100$$

the plus sign being used for subjects in negative balance; the minus sign for those in positive balance. The average requirement of the group by this method was found to be 662 mg. of calcium per day or 10.7 mg. per kg. per day. Calculated to a 70 kg. basis, this would be a daily requirement of about 750 mg. This is 67% higher than Sherman's (1) original figure of 450 mg. per day, the discrepancy being explained on the basis of the recent findings that the calcium of foods may be utilized only from 15 to 35% instead of completely. It is interesting to note that correcting Sherman's original figure of 0.45 g. for the average 20-30 per cent utilization, would bring his estimate to 1.5 to 2.2 g., which is in line with other recent findings.

Nature of Diet: Outhouse *et al* are careful to point out that their values apply only to their subjects on the experimental diet or closely similar diets with respect to the distribution and quantity of non-milk foods and identical with it in the proportion of milk calcium to non-milk calcium. The latter consideration is important inasmuch as there is some evidence that the calcium of plant foods may not be as well utilized as the calcium of milk (1a, 13a, 16, 16a).

Almost simultaneously with the studies of Outhouse *et al* (14, 15), Steggerda and Mitchell (17) reported further findings on their method

Table 1—The Calcium Requirement of Seven Adults

Subjects	Hb	Bm	Jo	Ws	Mh	Jd	Rd	Ave.
Weight in kg.	61	55	64	65	60	53	74	
Height in cm.	161	167	161	171	166	166	181	
Surface area in sq. m.[1]	1.64	1.61	1.66	1.75	1.64	1.57	1.93	
Total calcium intake (av. daily) in mg...	574	568	498	603	580	451	873	
Calcium balance (av. daily) in mg...	+24	+5	—39	—5	—13	—36	—22	
Utilization of milk calcium, %	35.1	30.6	30.3	20.1	17.6	15.3	20.4	24.2
Calcium requirement (total daily) in mg.	506	552	627	628	654	686	981	662
Calcium requirement (per kg.) in mg.....	8.3	10.0	9.8	9.7	10.9	12.9	13.3	10.7
Calcium requirement (per cm.) in mg.....	3.1	3.3	3.9	3.7	4.0	4.1	5.4	3.9
Calcium requirement (per sq. m.) in mg.[2]	309	344	376	359	400	438	508	391
Milk requirement (total daily) in gm.	236	281	360	313	353	405	615	

[1] Surface area was determined by the method of Boothby and Sandiford ('21).

[2] These are the quantities of milk which the subjects, in order to be in calcium equilibrium, would have to add to the non-milk foods used in this experiment.

of estimating calcium utilization and requirements from balance studies. Their data are summarized in Table 2.

The utilization of the supplementary calcium was computed by determining its sparing effect on the endogenous loss of calcium, at the same time correcting for any storage which may have occurred; in other words, by correcting to equilibrium values. The average calcium requirement for nine subjects obtained by this method was 9.55 mg. per kg. (± 0.46 mg. per kg.) which agrees well with the computed 10.0 mg. per kg. from Leitch's (2) data; the earlier estimation of 9.75 mg. per kg. of Mitchell and Curzon (3) and the value of 10.7 mg. per kg. of Outhouse *et al* (15).

During the course of this study it was found that the subjects had an average utilization of calcium from milk products of 29%, regardless of whether the source was fluid whole milk, liquid skim milk, dried milk solids or homogenized milk.

In the light of the newer findings of Steggerda and Mitchell and Outhouse and coworkers, the National Research Council in 1945 set its

Table 2—The Calcium Metabolism Data and Estimates of Utilization and Requirement Based On Them

Subject And Body Weight In Kg.	Calcium Supplement Tested	Test Period	Average Daily Metabolism of Calcium: Ca Intake		Ca Excreted		Balance	Utilization of Suppl. Calcium	Indicated Ca Requirement:	
			Basal Diet	Suppl. Food	In Feces	In Urine			Per kg. Body Weight	Per m.² Body Surface
		days	mg.	mg.	mg.	mg.	mg.	%	mg.	mg.
Ha	None	20	187	0	212	173	—198	....	.....	.....
69.8	Dry milk solids	24	198	543	513	193	+ 35	42	9.3	341
	Liquid skim milk	20	186	337	353	190	— 20	53	8.0	291
	Dry milk solids	20	209	337	390	166	— 10	52	8.2	293
Sp	None	20	176	0	173	180	—177	....	.....	.....
72.6	Dry milk solids	16	188	337	309	266	— 50	36	9.4	376
Na	None	16	187	.....	178	75	— 66	....	.....	.....
63.5	Dry milk solids	20	166	337	392	110	+ 1	21	7.8	288
	Liquid skim milk	20	199	337	434	104	— 2	18	8.6	316
Fa	None	32	165	0	168	76	— 79	....	.....	.....
55.8	Dry milk solids	32	172	410	459	113	+ 10	21	9.5	324
Cl	None	28	215	0	191	146	—122	....	.....	.....
62.6	Dry milk solids	20	272	528	616	198	— 14	18	14.0	499
St	None	20	195	0	216	82	—103	....	.....	.....
82.5	Liquid whole milk	16	213	431	548	105	— 9	21	8.3	340
	Homogenized milk	20	213	438	558	106	— 13	20	8.7	354
Fo	None	12	224	0	295	83	—154	....	.....	.....
65.8	Homogenized milk	16	211	435	595	85	— 34	28	11.7	433
Ma	None	20	258	0	263	98	—103	....	.....	.....
79.4	Liquid whole milk	20	227	430	487	142	+ 28	33	7.2	285
	Homogenized milk	20	290	438	556	128	+ 44	31	7.4	292
Ne	None	16	222	0	278	52	—108	....	.....	.....
74.8	Liquid whole milk	21	254	430	589	67	+ 28	29	7.9	295
	Homogenized milk	21	245	438	609	64	+ 10	26	8.6	322
	Homogenized milk	20	252	420	619	69	— 16	20	9.8	378
	Averages							29	9.55*	357*

*These values are the averages of the averages for the nine experimental subjects.

recommended daily allowance for calcium maintenance at 0.8 gram per day for all adults regardless of sex, activity or weight (18).

The New Calcium Recommendation for Adults:

In 1946, Steggerda and Mitchell (19) reviewed the evidence of calcium experiments conducted over a five-year period following their earlier studies in 1941. They studied the utilization of calcium in milk products or calcium salts (providing about 60% of the total dietary calcium) and the daily calcium requirement of 19 men. They found an average utilization of 32% and an average requirement of 9.2 mg. per kg. or 644 mg. daily. They reported extreme variations in individual utilization and postulated that because of such wide physiological variations, any effect of body size on requirements would undoubtedly be obscured.

Bringing together all their data, both new and old, they conclude:

> "A good average value for the calcium requirement of adult men and women of a nutritional status representative of college students and staff members*, subsisting on diets containing dairy products to furnish from one-half to two-thirds of the calcium content, is 10 mg. per kilogram of body weight per day. To cover the needs of all but 1 in 50, the total intake of calcium should be 14.51 mg. per kg. per day, or for a 70 kg. man, a total intake of 1.01 grams per day."

Studies with Self-Selected Diets:

The carefully controlled experimental diets cited in this Review by no means approximate the dietary pattern of the average American adult. It is interesting therefore to note the findings with respect to calcium requirement obtained from an analysis of individuals on uncontrolled diets of their own selection. A number of such studies have been reported, but because of space limitations only two will be considered here.

Young Women: In 1942, McKay and coworkers (20) reported studies on calcium, phosphorus and nitrogen intakes and retentions for (a) 124 college women from four states on the customary self-chosen diets; (b) one individual for 44 5-day periods during her 19 to 22 years; and (c) a group of nine young women eating basal diets supplemented with 1, 2 and 3 cups of milk respectively. Results showed no influence of place, age or weight for the group of 124 subjects and that intake and retention were significantly related. At least 0.8 gm. of calcium per day was required for equilibrium. The type of diet was shown to be an important factor influencing calcium retention as found by the larger percentage of calcium retention on controlled diets (milk supplemented) as compared with those on

*Subjects used in studies.

self-chosen diets *even when the calcium intakes were similar.* The authors explain this, saying:

> "Milk, the food most logically used to increase the calcium intake, improves the diet also in factors other than calcium and tends, therefore, to improve calcium retention."

They conclude, as a result of their observations, that:

> "In view of the fact that diets probably vary among the general population to a greater extent than did those used by the group of college women studied, the desirability of a generous calcium allowance for young women of college age (17 to 24) seems indicated, and the calcium allowance of 1.0 gm. recommended by the Committee on Foods and Nutrition of the National Research Council for girls of 16 to 20 might well be recommended for the group 17 to 24 years old."

Older Women: In April of this year, Roberts *et al* (21) reported similar studies on self-chosen diets in older women between the ages of 52 and 74. They found wide variations in food patterns and in requirements for calcium. Four of the nine subjects studied were losing calcium on self-chosen diets which ranged from 515 to 948 mg. of calcium per day. The mean requirement for equilibrium was found to be 14.1 mg. per kg., a figure considerably higher than the 9.2 or even 10.7 mg. per kg. averages of Steggerda and Mitchell (19) and Outhouse *et al* (15). It required approximately 1 gram of calcium per day to keep the average older woman in equilibrium, a fact of interest for two reasons: (1) Since calcium is almost insoluble in neutral solutions and it is known that a decrease in gastric acid occurs with age, this may be a measure of a real defect in the aging organism which must be met with adjustment of the diet. (2) Nine of these women averaged more than 600 mg. of calcium per day from mixed diets without milk or an added calcium salt. It required a calcium equivalent of one to three cups of milk per day to obtain equilibrium in addition to a diet containing meat, eggs, fruits, vegetables and generous amounts of cereals. No woman consumed enough cheese to substitute for this quantity of milk. Since the use of calcium salts (gluconate) may have affected the phosphorus balance adversely, the authors point out, it is necessary to study the effectiveness of calcium salts much more thoroughly before calcium in the salt form can be considered as a satisfactory substitute for milk. Roberts *et al* conclude that the calcium requirements of older women are higher than the previously proposed adult standard of 0.8 g. per day and suggest that at least 1 gm. of calcium per day is desirable for healthy older women.

On the basis of these newer findings, both experimental and clinical, the National Research Council again revised its recommendations for calcium (22), setting a level of 1.0 gm. per day for all adults.

REFERENCES CITED

1. SHERMAN, H. C. Calcium requirement of maintenance in man. *J. Biol. Chem.* 44, 21 (1920).

1a. SHERMAN, Henry C. *Calcium and Phosphorus in Foods and Nutrition.* Columbia University Press, New York, (1947).

2. LEITCH, I. The determination of the calcium requirements of man. *Nutr. Abstr. and Rev.* 6, 553 (1937).

3. MITCHELL, H. H. and E. G. Curzon. *The Dietary Requirement of Calcium and its Significance.* Paris, Hermann et Cie (1939).

4. BAUER, W., J. C. Aub and F. Albright. Studies of calcium and phosphorus metabolism. II. Calcium excretion of normal individuals on a low calcium diet. *J. Clin. Invest.* 7, 75 (1929).

5. STEGGERDA, F. R. and H. H. Mitchell. The calcium requirement of adult man and the utilization of the calcium in milk and in calcium gluconate. *J. Nutr.* 17, 253 (1939).

6. MALLON, M. G., R. Jordan and L. M. Johnson. A note on a high and low fat diet. *J. Biol. Chem.* 88, 163 (1930).

7. MALLON, M. G., L. M. Johnson and C. R. Darby. A study of the calcium retention on a diet containing American cheddar cheese. *J. Nutr.* 5, 121 (1932).

8. MALLON, M. G., L. M. Johnson and C. R. Darby. The calcium retention on a diet containing leaf lettuce. *J. Nutr.* 6, 303 (1933).

9. KRAMER, M. M., M. T. Potter and I. Gillum. Utilization by normal adult subjects of the calcium and phosphorus in raw milk and in ice cream. *J. Nutr.* 4, 105 (1931).

10. ADOLPH, W. H. and S. C. Chen. The utilization of calcium in soy bean diets. *J. Nutr.* 5, 379 (1932).

11. ROSE, M. S. and G. MacLeod. Experiments on the utilization of the calcium of almonds by man. *J. Biol. Chem.* 57, 305 (1923).

12. ROSE, M. S. Experiments on the utilization of the calcium of carrots by man. *J. Biol. Chem.* 41, 349 (1920).

13. KRAMER, M. M., E. Latzke and M. M. Shaw. A comparison of raw, pasteurized, evaporated and dried milks as sources of calcium and phosphorus for the human subject. *J. Biol. Chem.* 79, 283 (1928).

13a. SHIELDS, J. B., B. W. Fairbanks, G. H. Berryman and H. H. Mitchell. The utilization of calcium in carrots, lettuce and string beans in comparison with the calcium in milk. *J. Nutr.* 20, 263 (1940).

14. BREITER, H., R. Mills, J. Dwight, B. McKey, W. Armstrong and J. Outhouse. The utilization of the calcium of milk by adults. *J. Nutr.* 21, 351 (1941).

15. OUTHOUSE, J., H. Breiter, E. Rutherford, J. Dwight, R. Mills and W. Armstrong. The calcium requirement of man: balance studies on seven adults. *J. Nutr.* 21, 565 (1941).

16. FINCKE, M. L. and H. C. Sherman. The availability of calcium from some typical foods. *J. Biol. Chem.* 110, 421 (1935).

16a. SPEIRS, M. The utilization of the calcium of various greens. *J. Nutr.* 17, 557 (1939).

17. STEGGERDA, F. R. and H. H. Mitchell. Further experiments on the calcium requirement of adult man and the utilization of the calcium in milk. *J. Nutr.* 21, 577 (1941).

18. FOOD AND NUTRITION BOARD. *Recommended dietary allowances. Revised.* National Research Council Reprint and Circ. Series No. 122, Aug. (1945).

19. STEGGERDA, F. R. and H. H. Mitchell. Variability in the calcium metabolism and calcium requirement of adult human subjects. *J. Nutr.* 31, 407 (1946).

20. MCKAY, H., M. B. Patton, M. A. Ohlson, M. S. Pittman, R. M. Leverton, A. G. Marsh, G. Stearns and G. Cox. Calcium, phosphorus and nitrogen metabolism of young college women. *J. Nutr.* 24, 367 (1942).

21. ROBERTS, P. H., C. H. Kerrand, H. A. Ohlson. Nutritional status of older women. Nitrogen, calcium, phosphorus retentions of nine women. *J. Am. Diet. Assoc.* 24, 292 (1948).

22. FOOD AND NUTRITION BOARD. *Recommended dietary allowances. Revised.* National Research Council Reprint and Circ. Series No. 156, Nov. (1948).